E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(9): 792-797
Received: 03-07-2024
Accepted: 08-08-2024

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Effect of zinc sulphate and nano zinc in transplanted rice (*Oryza sativa* L.)

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i9Sk.1597

Abstract
The present experiment was conducted at Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (C. G.), Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during *kharif* season 2023-24. Research entitled with Effect of zinc sulphate and nano zinc on transplanted rice (*Oryza sativa* L.) along with recommended dose of fertilizer (100:60:40 NPK kg ha^{-1}). The experiment was presented in Randomized Block Design with three replications consisted of nine treatments. The results revealed that significantly higher growth and yield parameters was recorded under treatment T_6 RDF + Two spray of nano zinc at 45 DAT & 75 DAT Which was significantly superior over other treatments but was at par with T_9 RDF + Spray of 0.5% $ZnSO_4$ twice at 45 DAT & 75 DAT with closely followed by the treatment T_5, T_4. As compare to lowest recorded under T_1 RDF 100:60:40 NPK kg ha^{-1}.

Keywords: Rice, nano zinc, yield, $ZnSO_4$

1. Introduction

The foundation of the Indian economy, rice (*Oryza sativa* L.) is the most significant food crop in the world and a member of the Poaceae family. Rice is used as food crop for more then any of any crops primarily in East and Southeast Asia. The human diet and economy have been moulded by rice. Asia accounts for 90% of the world's paddy production and consumption. Rice has a high biological value for both carbohydrates and protein. It gives 20 per cent more energy per capita and 13% more protein globally. In terms of area, output, and consumption, rice is the most significant food crop in India. India's total rice production, which is grown over an area of roughly 48.50 million hectares with a productivity of 2809 kg ha^{-1}, fulfils the objective of 138.55 million tonnes in 2023–24. West Bengal is the top rice-producing region in India. In India, the average daily caloric intake is 2240 calories, of which only 20–30 per cent come from rice. (Anonymous, 2023-24) [3]. Among the cereal grains, rice is the most important crop in the state of Chhattisgarh. The main industries in Chhattisgarh are agriculture and forestry. The state's 70% of rural residents rely on rice farming for their daily sustenance. In India, the state of Chhattisgarh is referred to as a "bowl of rice." In Chhattisgarh, the total area and output under rice are 4.33 million hectares and 11.21 million tonnes, respectively, with a state productivity of 3212 kg ha^{-1}. (Anonymous, 2022-23) [3]. Norio Taniguchi coined the phrase “nanotechnology” in 1974. The term “nanotechnology” comes from the ‘Greek’ word “nanos,” which meaning “dwarf.” Nanotechnology is described as the study and management of materials with dimensions ranging from 1 to 100 nanometers, IFFCO developed a liquid fertiliser called Nano Zinc 10000 ppm, which is based on nanotechnology. Where unique physical features allow for novel applications. Nano particles: Nano particle is defined based on the size at which fundamental properties differ from those of the corresponding bulk material. Zinc is a crucial nutrient for plants, as it is needed for multiple biochemical functions in rice plants, such as membrane integrity and chlorophyll synthesis. Thus, plant turgor and colour are impacted by zinc deficits. Zinc is relatively stationary in soil and just marginally mobile in plants. Plants that are zinc deficient may be stunted, mature later, and produce less. Additionally, it renders leaves extremely heat- and light-sensitive. Many variables, such as pH, the amount of phosphorus in the soil, organic matter, clay content, calcium carbonate levels, soil drainage, and the concentration of iron and aluminium oxides, might affect the availability of zinc in the soil.

In rice, symptoms of zinc deficiency typically show up shortly after flooding and are most common in cold, rainy spring weather. Symptoms are most often seen in new growth, making in-season foliar applications of Zn is a good option for correction and zinc play role of co-factor for enzymatic activity in plant.

2. Materials and Methods

The study was conducted at Instructional Farm, the present experiment was conducted at Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during *Kharif* season 2023-24. Experiment was laid out in Randomized Block Design (RBD) with the nine treatments and three replications. The variety use for experiment rice 'Indira Barani Dhan-1' is short duration crop which mature in 120 days with high yield potential and this variety is drought tolerance rainfed crop. Crop was sown in first week of August and harvest in last week of October. The soil pH is 6.8 with clay loam in texture. The soil was categorized as medium in organic carbon (0.49%), low in available nitrogen (215 kg ha^{-1}) and medium in available phosphorus (13.93 kg ha^{-1}), Potassium content (215 kg ha^{-1}) organic carbon (0.49%) and medium zinc (0.78%) electrical conductivity (0.25 dSm^{-1} at 25 ºC). there were nine treatment combinations under experiment T_1: RDF (100:60:40) NPK kg ha^{-1}, T_2: RDF + Zn (5 kg ha^{-1}), T_3: RDF + Zn (10 kg ha^{-1}), T_4: RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT, T_5: RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT, T_6: RDF + Two spray of nano zinc at 45 & 75 DAT, T_7: RDF + Spray of 0.5% $ZnSO_4$ once at 45 DAT, T_8: RDF + Spray of nano zinc once at 45 DAT, T_9: RDF + spray of 0.5% $ZnSO_4$ Twice at 45 & 75 DAT. Indira Barani Dhan-1' variety was sown by line transplanting method with a row spacing of 20 cm and plant to plant spacing 10 cm and seed rate was 40 kg ha^{-1} used for 1000 m^2 area nursery. The recommended dose of fertilizers for transplanted rice are 100: 60: 40 of N, P_2O_5, K_2O kg ha^{-1}, respectively. Full dose of P_2O_5, K_2O and 50% of Nitrogen were applied at the time of transplanting and 50% Nitrogen at panicle initiation stage. Plant protection measures and irrigations were provided as and when required for all the treatments. Regular growth observations were recorded at periodic intervals of 30, 60, 90 DAT and at harvest stage of randomly selected plants. Growth parameters were recorded just before harvesting of crop. Harvesting was done when the panicle matured and plant was dried up. The threshing of the crop was done by manually by plot wise and grain and straw were conducted separately. The grain yield was recorded as kg $plot^{-1}$ and then calculated into q ha^{-1}. The straw yield was calculated by the subtracting grain yield from the biological yield. Statistical data were analyzed by standard procedure by Gomez and Gomez (1984).

3. Results and Discussion

The results of analysis of variance showed a highly significant difference among the applied treatments for all growth and yield attributing characters. Effect of the foliar application with different combination of nano-zinc and zinc sulphate were studied

3.1 Plant height (cm)

A significant effect of zinc sulphate and nano zinc fertilizer was observed on plant height at all the crop growth stages till harvest. At 30 DAT maximum plant height (54.95 cm) recorded under Treatment T_3 (RDF + Zn (10 Kg ha^{-1}) and it's followed by T_5 (52.34 cm), T_2 (51.12 cm) and T_4 (50.54 cm) and it was significantly superior over all other treatments due to basal application of zinc sulphate with RDF. At 60 DAT maximum plant height observed in T_5 (93.60 cm) RDF + Zn 5 kg ha^{-1} + spray of nano zinc at 45 DAT and it's followed by treatment T_4 (91.61 cm) T_6 (89.84 cm), which was significantly superior then over all other treatments At 90 DAT and at harvest maximum height observed (125.80 cm) in treatment T_6 RDF + Two spray of nano zinc at 45 DAT & 75 DAT and it was at par with T_9, T_5, T_4 and it was significantly superior then over all other treatments. The significantly lowest plant height recorded under treatment T_1 (RDF 100:60:40 NPK kg ha^{-1})

3.2 Number of tillers $hill^{-1}$

The application of different treatments shows significant effect on the number of tillers throughout the entire phase. At 30 DAT maximum number of tillers were recorded under treatment T_3 (8.40) with the application of RDF + Zn (10 kg ha^{-1}) which was at par with T_5 (8.15) RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT, T_2 (7.77) RDF + Zn (5 kg ha^{-1}). T_4 (7.46) RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT. At 60 DAT maximum number of tillers were observed under treatment T_5 (10.89) with the application of RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT which was at par with T_4 RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT, T_6 RDF + Two spray of nano zinc at 45 & 75 DAT and T_9. At 90 DAT and at harvest stage maximum number of tillers were observed (12.92) and (12.19) respectively under treatment T_6 with the application of RDF + Two spray of nano zinc at 45 & 75 DAT which was at par with T_9, T_5, T_4. however, it is significantly superior over treatment T_8, T_7, T_3 and T_2. The minimum number of tillers were observed (8.59) under treatment T_1 (RDF 100:60:40 NPK kg ha^{-1}).

3.3 Number of Panicle $hill^{-1}$

The use of zinc sulphate and nano zinc fertilizer had significant effect on the number of panicle $hill^{-1}$ observation taken of panicle length was statistically analyzed. Among the applied treatment T_6 observed (12.48) under treatment RDF + Two spray of nano zinc at 45 & 75 DAT which was significantly higher number panicle $hill^{-1}$ over the other treatment however it was followed by treatment T_9 (12.05), T_5 (11.89) and T_4 (11.48) lowest panicle length was observed (8.67) when treated with treatment T_1 RDF (100:60:40 NPK kg ha^{-1}).

3.4 Dry matter accumulation (g $hill^{-1}$)

The Dry matter accumulation (g $hill^{-1}$) was recorded at regular interval of 30, 60, 90 DAT and at harvest. The application of different treatments shows significant effect on the Dry matter accumulation (g $hill^{-1}$) throughout the entire phase. At 30 DAT maximum Dry matter accumulation (g $hill^{-1}$) were observed (13.78 g $hill^{-1}$) under treatment T_3 with the application of RDF + Zn (10 kg ha^{-1}) which was at par with T_5 (13.45) RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT, T_4 (12.11) RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT, T_2 (12.89) RDF + Zn (5 kg ha^{-1}). At 60 DAT maximum Dry matter accumulation (g $hill^{-1}$) were recorded (64.38 g $hill^{-1}$) under treatment T_5 with the application of RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT which was at par with T_4, T_6 and T_9. At 90 DAT stage maximum Dry matter accumulation were observed (121.42 g $hill^{-1}$) under treatment T_6 with the application of RDF + Two spray of nano zinc at 45 & 75 DAT which was at par with T_9, T_5, T_4. At harvest stage maximum Dry matter accumulation were observed (136.31 g $hill^{-1}$) under treatment T_6 with the application of RDF + Two spray of nano zinc at 45 & 75 DAT which was at par with T_9 (132.97), T_5 (129.43), T_4 (125.91).

however, it is significantly superior over treatment T_8, T_7, T_3 and T_2. The minimum Dry matter accumulation was observed (104.77 g $hill^{-1}$) under treatment T_1 RDF (100:60:40 NPK kg ha^{-1}).

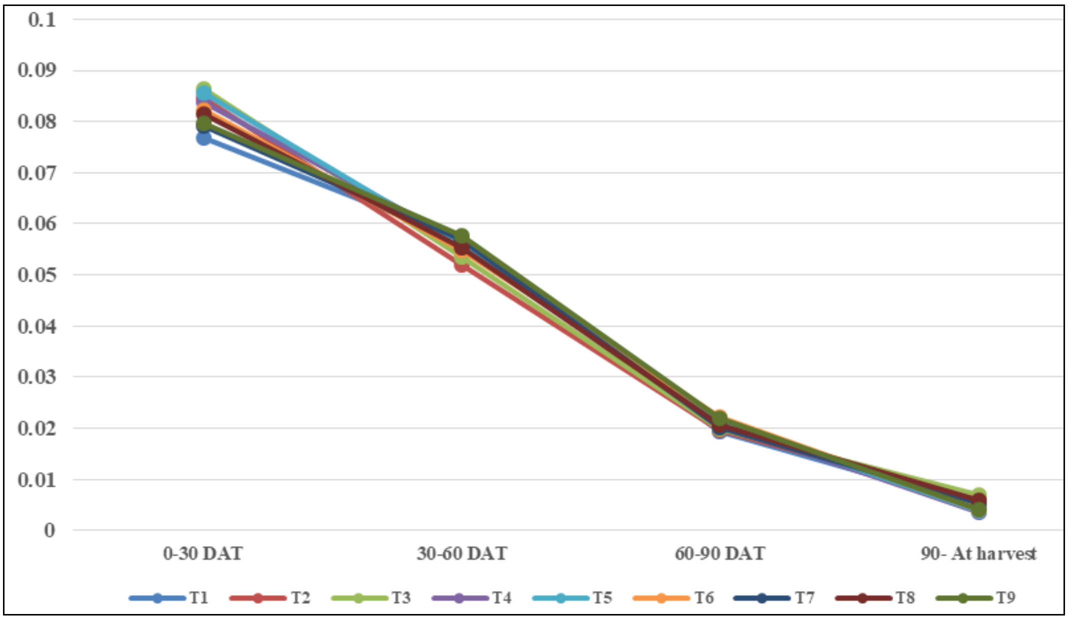

Fig 1: Crop growth rate (CGR) (g day^{-1} $hill^{-1}$)

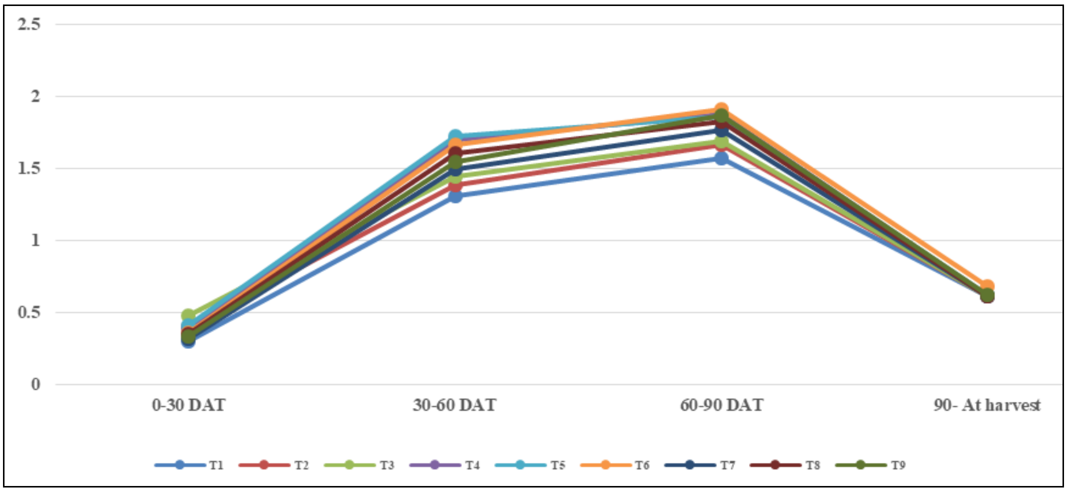

Fig 2: Relative growth rate (g g^{-1} day^{-1})

3.5 Panicle length (cm)

The use of zinc sulphate and nano zinc had a significant effect on panicle length (cm) among the applied treatments T_6 RDF + Two spray of nano zinc at 45 & 75 DAT observed in significantly higher panicle length (25.72 cm) over the treatments in comparison. However, it was at par with treatment T_9 (23.97 cm) RDF + Spray of 0.5% $ZnSO_4$ twice at 45 & 75 DAT, T_5 (22.41 cm) RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT, T_4 (21.23 cm) RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT. Lowest panicle length observed (15.43 cm) when treated with T_1 RDF (100:60:40 NPK kg ha^{-1})

3.6 Number of grains panicle^{-1}

The data denoting the number of grains $panicle^{-1}$ of rice significantly influenced by treatment of zinc sulphates and nano zinc. It was observed that maximum grains $panicle^{-1}$ (148.51) was observed under treatment T_6 with application of RDF + Two spray of nano zinc at 45 & 75 DAT. However, it was at par with T_9 (146.01) RDF + Spray of 0.5% $ZnSO_4$ twice at 45 & 75 DAT, T_5 (142.35) RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT, T_4 (139.42) RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT. Minimum number of grains $panicle^{-1}$ was observed under (123.70) treatment T_1 RDF (100:60:40 NPK kg ha^{-1}).

3.7 Test weight (g)

Test weight of rice was found to be non-significant difference by Different treatment applied Due to similar size and morphology of seed is similar which result non-significant test weight. However, it was observed that maximum test weight was obtained (23.84 g) under treatment T_6 RDF + Two spray of nano zinc at 45 & 75 DAT However, lowest test weight (g) was recorded (17.47 g) under treatment T_1 RDF (100:60:40 NPK kg ha^{-1})

3.8 Grain yield (q ha^{-1})

Maximum grain yield is due to application of T_6 RDF + Two spray of nano zinc at 45 & 75 DAT might be due to accumulation of assimilates and combined effect of growth and yield attributes Among the applied treatments higher grain yield (49.52 q ha^{-1}) was recorded under treatment T_6 RDF + Two spray of nano zinc at 45 & 75 DAT. However, T_6 followed by T_9 (48.08 q ha^{-1}) RDF + Spray of 0.5% $ZnSO_4$ twice at 45 & 75 DAT, T_5 (46.54 q ha^{-1}) RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT, T_4 (45.39 q ha^{-1}) RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT. However, lowest grain yield (40.03 q ha^{-1}) under treatment T_1 RDF (100:60:40 NPK kg ha^{-1})

3.9 Straw yield (q ha^{-1})
The maximum straw yield differed significantly with respect to sowing methods and levels of zinc application. The maximum straw yield was observed (58.50 q ha^{-1}) in T_6 RDF + Two spray of nano zinc at 45 DAT & 75 DAT. T_6 recorded significantly higher yield which was at par with T_9 (57.30 q ha^{-1}) RDF + Spray of 0.5% $ZnSO_4$ twice at 45 DAT & 75 DAT, T5 (56.25 q ha-1) RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT, T4 (55.40 q ha^{-1}) RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT. T_1 produce (51.48 q ha^{-1}) significantly less straw yield in comparison to all other treatment supplied RDF (100:60:40 NPK kg ha^{-1})

3.10 Harvest index (%)
The maximum harvest index differed significantly with respect to sowing methods and levels of fertilizer application. Highest harvest index was obtained under treatment T_6 (45.84%) with the application of RDF + Two spray of nano zinc at 45 & 75 DAT. However, lowest harvest index was obtained under treatment T_1 (43.74%) RDF (100:60:40 NPK kg ha^{-1}).

3.11 Economics
The data pertaining to cost of cultivation (₹ ha^{-1}), gross return (₹ ha^{-1}), net return (₹ ha^{-1}) and B: C ratio. The highest cost of cultivation, highest gross return, maximum net return, maximum B:C ratio was observed under treatment T_6 with the application of RDF + Two spray of nano zinc at 45 & 75 DAT, However, minimum cost of cultivation (₹ ha^{-1}), gross return (₹ ha^{-1}), net return (₹ ha^{-1}) and B: C ratio was obtained under treatment T_1 RDF (100:60:40 NPK kg ha^{-1}).

3.12 Zinc concentration in grain and straw (mg kg^{-1})
Concentration of zinc in grain and straw as influenced by different soil and foliar application of Zn. Zinc concentration and uptake was significantly influenced by basal and foliar application of Zn. There was increase in Zn concentration in different plant parts with increasing levels of Zn application. Among various treatments maximum Zn concentration in grain and straw (26.75 and 35.34 mg kg^{-1}) was observed under treatment T_6 RDF + Two spray of nano zinc at 45 & 75 DAT. followed by (25.97 and 33.98 mg kg^{-1}) in T_9 RDF + Spray of 0.5% $ZnSO_4$ twice at 45 & 75 DAT Significantly lowest Zn concentration was recorded in grain and straw (16.98 and 24.45 mg kg^{-1}) in treatment T_1 RDF (100:60:40 NPK kg ha^{-1}) There was significant increase in zinc content in grain and straw due to zinc application among treatments. Zinc content in straw that of grain which showed similar result with Naik S. and Das D.K. (2007).

3.13 Zinc uptake (g ha^{-1})
Uptake of zinc mostly depends upon concentration in grain and straw as well as grain and straw yield. Hence Zn content in grain multiplied with yield will give value to uptake by grain and same in case of straw. There was a significant increase in uptake of Zn by grain and straw among the treatments. Maximum uptake of 132.46 and 206.73 g ha^{-1} in grain and straw respectively was obtained T_6 RDF + Two spray of nano zinc at 45 & 75 DAT where the total Zn uptake was found to be 15% higher than that of soil application of $ZnSO_4$. Indicate deficient uptake of nano Zn. The present results are in the agreement with the results reported by Jangid *et al*., (2019) [7] where he found higher uptake by application of nano zinc in comparison to soil application. The uptake being the product of content and dry matter production, the increase in Zn uptake by the crop due to easily available and fast rate of absorption caused by increase mobility when micronutrient applied as foliar spray.

Table 1: Growth and growth attributes of transplanted rice (*Oryza sativa* L.) as influence by zinc sulphate and nano zinc

Tr. No.	Treatment Details	Plant height (cm)	Number of tillers hill^{-1}	Number of panicle hill^{-1}	Dry matter accumulation (g)
T_1	RDF (100:60:40 NPK kg ha^{-1})	93.25	8.12	8.67	104.77
T_2	RDF + Zn (5 kg ha^{-1})	95.27	8.81	9.47	108.18
T_3	RDF + Zn (10 kg ha^{-1})	99.15	9.43	9.93	110.87
T_4	RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT	112.63	10.84	11.48	125.91
T_5	RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT	115.18	11.04	11.89	129.43
T_6	RDF + Two spray of nano zinc at 45 & 75 DAT	122.73	12.39	12.48	136.31
T_7	RDF + Spray of 0.5% $ZnSO_4$ once at 45 DAT	102.32	9.88	10.21	116.61
T_8	RDF + Spray of nano zinc once at 45 DAT	107.23	10.18	10.68	121.82
T_9	RDF + Spray of 0.5% $ZnSO_4$ twice at 45 & 75 DAT	119.96	11.71	12.05	132.97
	SEm (±)	3.84	0.68	0.50	3.54
	CD (0.05)	11.52	2.06	1.46	10.63

Table 2: Yield and yield attributes of transplanted rice (*Oryza sativa* L.) as influence by zinc sulphate and nano zinc

Tr. No	Treatment Details	Panicle length (cm)	Number of grain panicle^{-1}	Test weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
T_1	RDF (100:60:40 NPK kg ha^{-1})	15.23	123.70	17.47	40.03	51.48	43.74
T_2	RDF + Zn (5 kg ha^{-1})	16.98	126.09	18.16	41.26	52.59	43.96
T_3	RDF + Zn (10 kg ha^{-1})	17.30	129.17	18.84	42.33	53.65	44.10
T_4	RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT	21.23	139.72	21.29	45.39	55.40	45.03
T_5	RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT	22.41	142.35	21.81	46.54	56.25	45.27
T_6	RDF + Two spray of nano zinc at 45 & 75 DAT	25.72	148.51	23.84	49.52	58.50	45.84
T_7	RDF + Spray of 0.5% $ZnSO_4$ once at 45 DAT	18.61	134.56	19.89	43.13	54.27	44.28
T_8	RDF + Spray of nano zinc once at 45 DAT	19.27	137.48	20.15	44.01	54.85	44.51
T_9	RDF + Spray of 0.5% $ZnSO_4$ twice at 45 & 75 DAT	23.97	146.01	22.68	48.08	57.30	45.62
	SEm (±)	1.68	3.25	1.08	1.83	1.16	
	CD (0.05)	5.04	9.76	3.24	5.49	3.48	

Table 3: Economics of transplanted rice

Tr. No.	Treatment Details	Cost of cultivation (₹ ha^{-1})	Gross monetary return (₹ ha^{-1})	Net monetary return (₹ ha^{-1})	B: C Ratio
T_1	RDF (100:60:40 NPK kg ha^{-1})	45795	129241	83446	1.82
T_2	RDF + Zn (5 kg ha^{-1})	46395	133165	86770	1.87
T_3	RDF + Zn (10 kg ha^{-1})	47295	136598	89303	1.88
T_4	RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT	46885	146249	100014	2.13
T_5	RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT	47335	149899	102564	2.16
T_6	RDF + Two spray of nano zinc at 45 DAT & 75 DAT	47375	159362	111987	2.36
T_7	RDF + Spray of 0.5% $ZnSO_4$ once at 45 DAT	45985	139130	93145	2.02
T_8	RDF + Spray of nano zinc once at 45 DAT	46435	142089	95654	2.05
T_9	RDF + Spray of 0.5% $ZnSO_4$ twice at 45 DAT & 75 DAT	46475	154778	108303	2.33

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Table 4: Zinc concentration in grain and straw (mg kg^{-1}) of transplanted rice (*Oryza sativa* L.) as influence by zinc sulphate and nano zinc

Tr. No.	Treatment details	Zn concentration (mg kg^{-1})	
		Grain	Straw
T_1	RDF (100:60:40 NPK kg ha^{-1})	16.98	24.45
T_2	RDF + Zn (5 kg ha^{-1})	18.53	25.29
T_3	RDF + Zn (10 kg ha^{-1})	19.15	27.21
T_4	RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT	22.69	32.08
T_5	RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT	23.67	33.09
T_6	RDF + Two spray of nano zinc at 45 DAT & 75 DAT	26.75	35.34
T_7	RDF + Spray of 0.5% $ZnSO_4$ once at 45 DAT	20.31	29.95
T_8	RDF + Spray of nano zinc once at 45 DAT	21.55	31.22
T_9	RDF + Spray of 0.5% $ZnSO_4$ twice at 45 DAT & 75 DAT	25.57	33.98
	SEm (±)	0.95	1.00
	CD (0.05)	2.78	2.92

Table 5: Zinc uptake by grain and straw (g ha^{-1}) of transplanted rice (*Oryza sativa* L.) as influence by zinc sulphate and nano zinc

Tr. No.	Treatment details	Zn uptake (g ha^{-1})		
		Grain	Straw	Total uptake
T_1	RDF (100:60:40 NPK kg ha^{-1})	67.94	125.86	193.8
T_2	RDF + Zn (5 kg ha^{-1})	77.69	133.00	210.69
T_3	RDF + Zn (10 kg ha^{-1})	81.06	145.98	227.04
T_4	RDF + Zn (2.5 kg ha^{-1}) + nano zinc spray at 45 DAT	102.98	177.72	280.7
T_5	RDF + Zn (5 kg ha^{-1}) + nano zinc spray at 45 DAT	110.16	186.13	296.29
T_6	RDF + Two spray of nano zinc at 45 DAT & 75 DAT	132.46	206.73	339.19
T_7	RDF + Spray of 0.5% $ZnSO_4$ once at 45 DAT	87.46	162.53	249.99
T_8	RDF + Spray of nano zinc once at 45 DAT	94.84	171.53	266.37
T_9	RDF + Spray of 0.5% $ZnSO_4$ twice at 45 DAT & 75 DAT	122.94	194.70	317.64
	SEm (±)	3.09	4.01	7.15
	CD (0.05)	8.11	10.34	22.03

Conclusion

On the basis of one season experiment on rice (*Oryza sativa* L.) treatment T_6 - RDF + Two spray of nano zinc at 45 & 75 DAT was found more effective in growth and yield attributing character, higher grain yield, economical parameters and higher concentration of zinc and uptake of zinc in grain and straw.

Acknowledgment

I express my heartful gratitude to my major advisor Dr. T. D. Pandey and all members of advisory committee and all staff of Department of Agronomy for constant support and guidance to carry out the whole experimental research study.

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